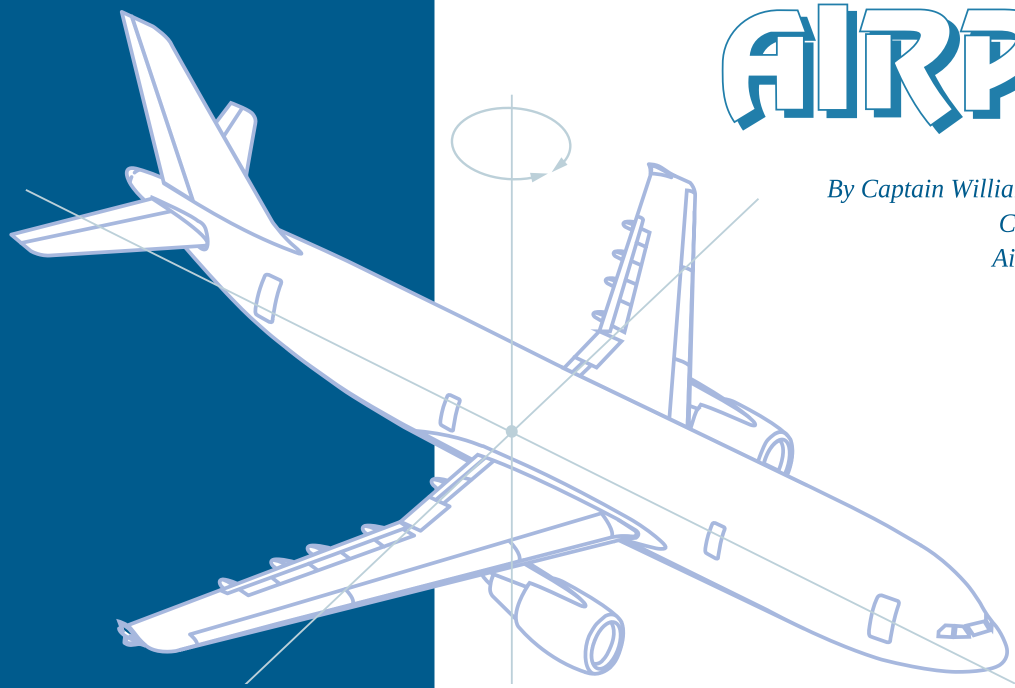


AIRPLANE UPSET RECOVERY

A test pilot's point of view

By Captain William Wainwright
Chief Test Pilot
Airbus Industrie

The idea for a joint industry working group to produce an Airplane Upset Recovery Training Aid was first proposed by ATA in June 1996. It was in response to increasing interest by the NTSB in aircraft loss of control accidents which, together with Controlled Flight Into Terrain, cause a large proportion of all accidents. They were putting a lot of pressure on the FAA to produce new regulations covering this subject.*

The working group was a voluntary industry initiative to see what could be done within the existing regulations to improve the situation.

The joint industry team consisted of representatives of all sides of industry: aircraft manufacturers, airlines, governmental authorities, and pilots' unions. It was a good example of how the entire industry, designers, users, and regulators can co-operate on safety issues that are common to everyone. It also marked a "first" in showing that the "Big 3" aircraft manufacturers could and will work together on technical, non-commercial issues. More than 80 persons coming from all around the world, but principally from the USA, participated from time to time.

The end result of two years work is a training package including a video and a CD-ROM, giving an airplane upset recovery training aid. This package is on free issue to all our customers, to use as they wish. However, all members of the joint industry group agreed that the package is aimed at preventing loss of control accidents on conventional aircraft. It is not aimed at protected Fly-by-Wire aircraft.

There is no need for this type of continuation training on protected aircraft, although a general knowledge of the principles involved is useful for every pilot.

The content of the package is not the subject of this article, but there are a few issues of general interest which I gained from my experience as a member of the working group which I would like to mention.

** The Training Aid itself was the basis of the article entitled "AERODYNAMIC PRINCIPLES OF LARGE AIRCRAFT UPSETS" that appeared as a Special Edition of FAST in June 1998.*

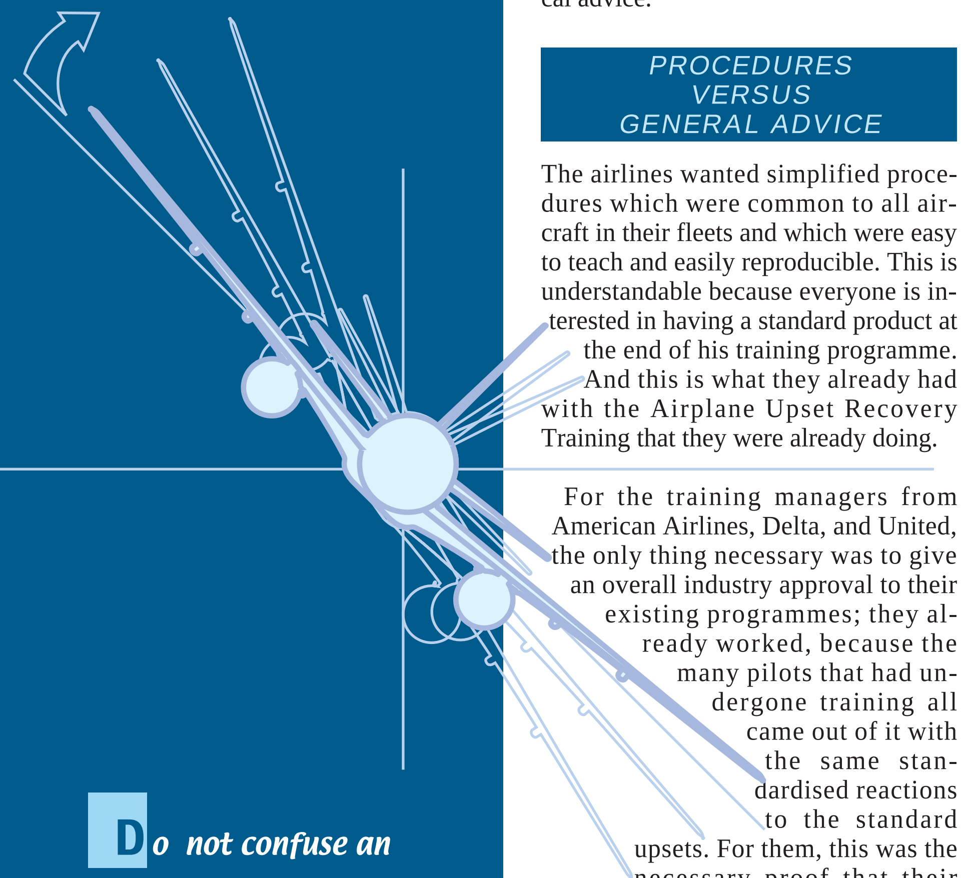
THE BEGINNING

The issue of upset training was not new; major airlines around the world, and in particular in the USA, had already produced Upset Recovery Training Programmes, or were using one produced by another company. Amongst the members of the group were training pilots from American Airlines, Delta, and United who were already running such training programmes in their simulators. Since this was essentially seen as a training issue. Initially the Flight Test Departments of the three main manufacturers were not involved. Airbus was represented by Larry Rockliff, Chief Pilot at Airbus Training Centre in Miami. Right from the beginning there was a conflict between the technical advice given by the manufacturers' training pilots and that expressed by those of the principal airlines already practising upset training. They naturally considered themselves to be the experts on this subject, based on the many hours of training that they had already conducted on a large number of pilots in their simulators.

At the beginning of 1997, the Flight Test Departments were asked to come in to support their training pilots. From then on, the chief test pilots of the three major manufacturers became members of the working group. But the conflict over the different opinions on aircraft handling and recovery techniques continued for a long time until we finally achieved agreement at the last meeting in January 1998. The reasons for these differences of opinion are the subject of this article.

There is no need for this type of continuation training on protected fly-by-wire aircraft

If altitude permits, flight tests have shown that an effective method to get a nose-down pitch rate is to reduce the power on underwing mounted engines.



Do not confuse an approach to the stall and a full stall. An approach to stall is controlled flight. An airplane that is stalled is out of control and must be recovered.

THE DIFFERENCES OF OPINION

The differences of opinion were mainly concentrated in the following areas:

- Procedures versus general advice
- Ease of training versus failure cases
- Stalling
- Use of rudder
- Use of simulators.

It is worth saying that there was never any difference of opinion between the three test pilots on the group. Although we come from different backgrounds and have worked in different organisations with different work cultures, we always agreed on our technical advice.

PROCEDURES VERSUS GENERAL ADVICE

The airlines wanted simplified procedures which were common to all aircraft in their fleets and which were easy to teach and easily reproducible. This is understandable because everyone is interested in having a standard product at the end of his training programme. And this is what they already had with the Airplane Upset Recovery Training that they were already doing.

For the training managers from American Airlines, Delta, and United, the only thing necessary was to give an overall industry approval to their existing programmes; they already worked, because the many pilots that had undergone training all came out of it with the same standardised reactions to the standard upsets. For them, this was the necessary proof that their training programme worked.

Where we differed was in our conviction that there is no such thing as a standard upset and our reluctance to endorse simplified procedures for recovery from an upset.

We wanted a general knowledge based approach, as opposed to a rule based one. For this, after proposing some initial actions, we talk about "additional techniques which may be tried". This obviously is more difficult to teach.

Where we reached a compromise was in the order of presenting the various actions that might be considered to recover the situation. For us, the order of presentation is for guidance only; it represents a series of options that should be considered and used as appropriate to the situation. It is not meant to represent rigid procedures that must be followed in an exact sequence. However, the order can be used in training scenarios if a procedural approach is needed for training.

The airline instructors also wanted procedures which would apply to all the aircraft in their fleets. This meant that they were against certain actions, because they were inappropriate on others. For example, the thrust effects of underwing-mounted engines were being ignored, whereas it has a significant influence on recovery. Again, we reached a compromise by using the following words: " if altitude permits, flight tests have shown that an effective method to get a nose-down pitch rate is to reduce the power on underwing-mounted engines".

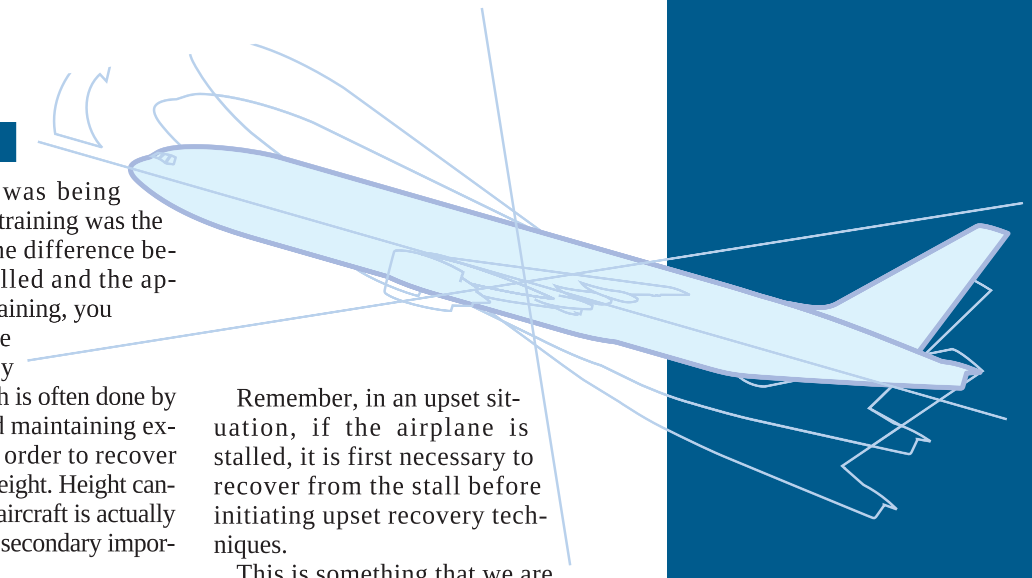
EASE OF TRAINING VERSUS FAILURE CASES

The training that was already being done, considered upsets as being due to momentary inattention, with a fully serviceable aircraft, that was in trim when it was upset. We wanted to consider other cases that involve aircraft with temporarily insufficient control authority for easy recovery. This of course complicates the situation, because recovering an aircraft which is in trim, possessing full control authority and normal control forces, is not the same as recovering an aircraft with limited control available or with unusual control forces.

Thus, for us, an aircraft that is out-of-trim, for whatever reason, should be re-trimmed. Whereas the airline instructors were against the use of trim because of concerns over the possibility of a pilot overtrimming and of trim runaways which are particularly likely on some older aircraft types which are still in their fleets.

We spent a lot of time discussing the use of elevator trim and we never reached agreement. All the major US airlines were adamant on their policy to recover first using "primary controls" which excluded any reference to trimming.

Again, a compromise was necessary. What we have done is to talk about using trim if a sustained column force is required to obtain the desired response whilst mentioning that care must be used to avoid using too much trim. And, the use of trim is not mentioned in the simplified lists of actions to be taken.



STALLING

Another aspect that was being ignored in the existing training was the stall. By this I mean the difference between being fully stalled and the approach to the stall. In training, you do an approach to the stall with a recovery from stick shaker, which is often done by applying full thrust and maintaining existing pitch attitude in order to recover with minimum loss of height. Height cannot be maintained if an aircraft is actually stalled and should be of secondary importance.

Even those pilots who do stalls on airtests, as might be done after a heavy maintenance check, only do them with gentle decelerations, and they recover immediately without penetrating very far beyond the stalling angle of attack. There is a world of difference between being just before, or even just at, the stall, and going dynamically well into it.

When we started our discussions, the training being given in the airlines to recover from excessive nose-up pitch attitudes emphasised rolling rapidly towards 90° of bank. This is fun to do, and it was not surprising to find that most of the instructors doing the training were ex-fighter pilots who had spent a lot of time performing such manoeuvres in another life. The training was being done in the same way, with an aircraft starting in trim with a lot of energy and recovering while it still had some. However, the technique being taught only works if the aircraft is not stalled.

We start our briefing on recovery techniques with the following caution:

Recovery techniques assume that the airplane is not stalled. If the airplane is stalled, it is imperative to first recover from the stalled condition before initiating the upset recovery technique.

Do not confuse an approach to the stall and a full stall. An approach to stall is controlled flight. An airplane that is stalled is out of control and must be recovered.

A stall is characterised by any, or a combination of the following:

- Buffeting, which could be heavy at times
- Lack of pitch authority
- Lack of roll control
- Inability to arrest descent rate.

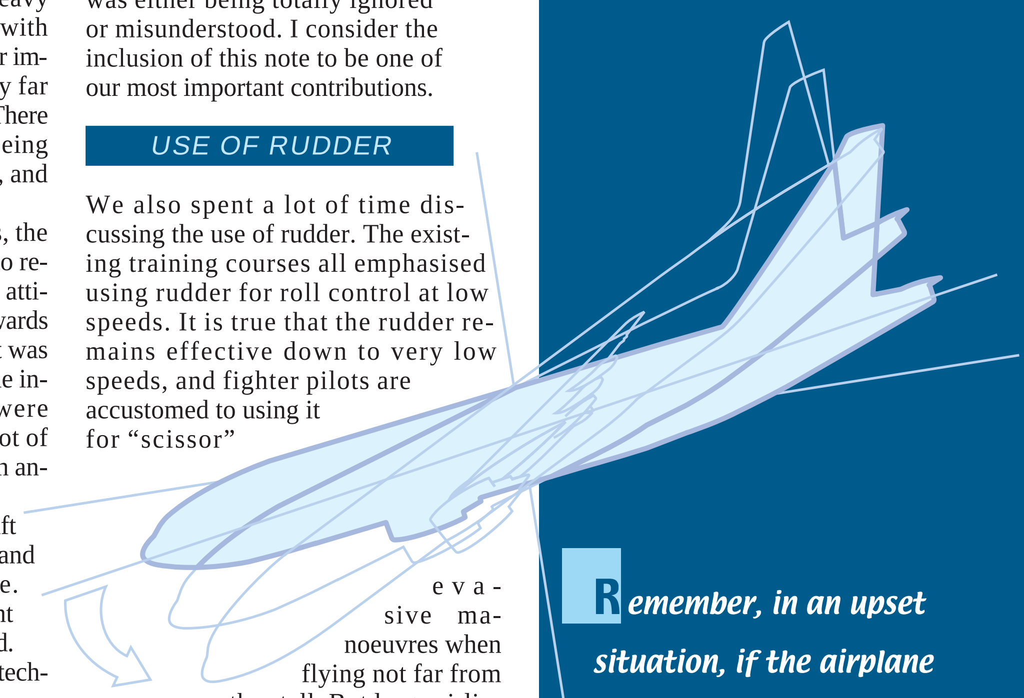
To recover from a stall, the angle of attack must be reduced below the stalling angle. Apply nose down pitch control and maintain it until stall recovery. Under certain conditions with under-wing mounted engines, it may be necessary to reduce thrust to prevent the angle of attack from continuing to increase.

Remember, in an upset situation, if the airplane is stalled, it is first necessary to recover from the stall before initiating upset recovery techniques.

This is something that we are well aware of in testing, but it was either being totally ignored or misunderstood. I consider the inclusion of this note to be one of our most important contributions.

USE OF RUDDER

We also spent a lot of time discussing the use of rudder. The existing training courses all emphasised using rudder for roll control at low speeds. It is true that the rudder remains effective down to very low speeds, and fighter pilots are accustomed to using it for "scissor" evasive manoeuvres when flying not far from the stall. But large airliners, with all the inertias that they possess, are not like fighter aircraft. Based on our experience as test pilots we are very wary of using rudder close to the stall. It is the best way to provoke a loss of control if not used very carefully, particularly with flaps out.



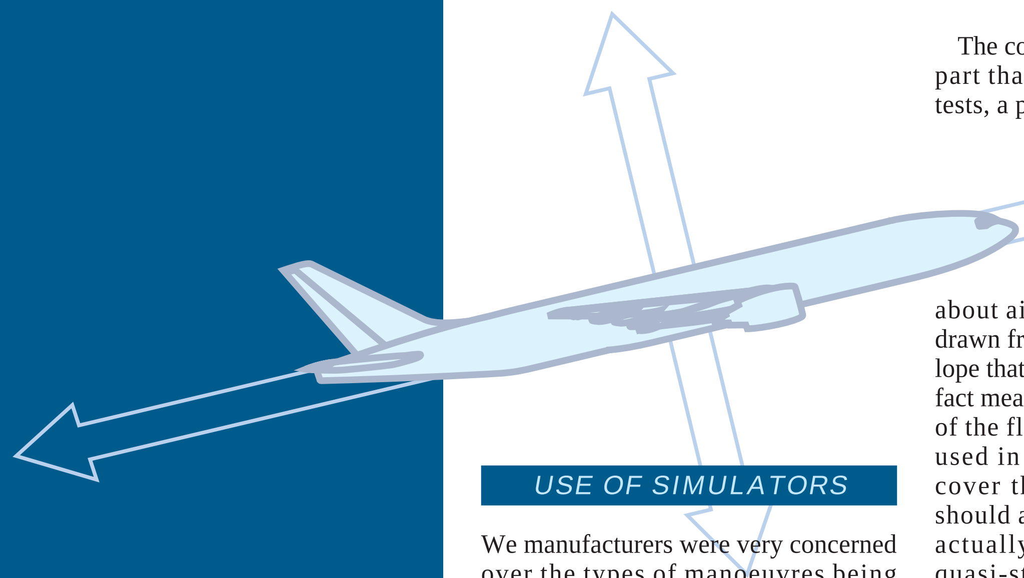
We finally got the training managers to agree to play down the use of rudder in their existing courses. But we do not say never use the rudder at low speed. We say that, if necessary, the aileron inputs can be assisted by coordinated rudder in the direction of the desired roll. However, we also caution that "excessive rudder can cause excessive sideslip, which could lead to departure from controlled flight".

But why did we have so much difficulty in convincing the training pilots that it is not a good idea to go kicking the rudder around at low speed?

Their reply was always the same; but it works in the simulator! This leads me on to my last point.

Remember, in an upset situation, if the airplane is stalled, it is first necessary to recover from the stall before initiating upset recovery techniques.

Excessive rudder can cause excessive sideslip, which could lead to departure from controlled flight.



Simulators should not be used to develop techniques at the edges of the flight envelope.

USE OF SIMULATORS

We manufacturers were very concerned over the types of manoeuvres being flown in simulators and the conclusions that were being drawn from them. Simulators, like any computer system, are only as good as the data that goes into them. That means the data package that is given to the simulator manufacturer. And we test pilots do not deliberately lose control of our aircraft just to get data for the simulator. And even when that happens, one isolated incident does not provide much information because of the very complicated equations that govern dynamic manoeuvres involving non-linear aerodynamics and inertia effects.

The complete data package includes a part that is drawn from actual flight tests, a part that uses wind tunnel data, and the rest which is pure extrapolation. It should be obvious that firm conclusions about aircraft behaviour can only be drawn from the parts of the flight envelope that are based on hard data. This in fact means being not far from the centre of the flight envelope; the part that is used in normal service. It does not cover the edges of the envelope. I should also add that most of the data actually collected in flight is from quasi-static manoeuvres. Thus, dynamic manoeuvring is not very well represented. In fact, a typical data package has flight test data for the areas described in Table 1.

In other words, you have reasonable cover up to quite high sideslips and quite high angles of attack (AOA), but not at the same time. Furthermore, the matching between aircraft stalling tests and the simulator concentrates mainly on the longitudinal axis. This means that the simulator model is able to correctly reproduce the stalling speeds and the pitching behaviour, but fidelity is not ensured for rolling efficiency (based on a simplified model of wind tunnel data) or for possible asymmetric stalling of the wings. Also, the range for one engine inoperative is much less than the range for all engines operating and linear interpolation is assumed between low and high Mach numbers. Wind tunnel data goes further. For example, a typical data package would cover the areas described in table 2.

In fact, this is a perfectly adequate coverage to conduct all normal training needs. But it is insufficient to evaluate recovery techniques from loss of control incidents. Whereas, the training managers were all in the habit of demonstrating the handling characteristics beyond the stall; often telling their trainees that the rudder is far more effective than aileron and induces less drag and has no vices! In short, they were developing handling techniques from simulators that were outside their guaranteed domain.

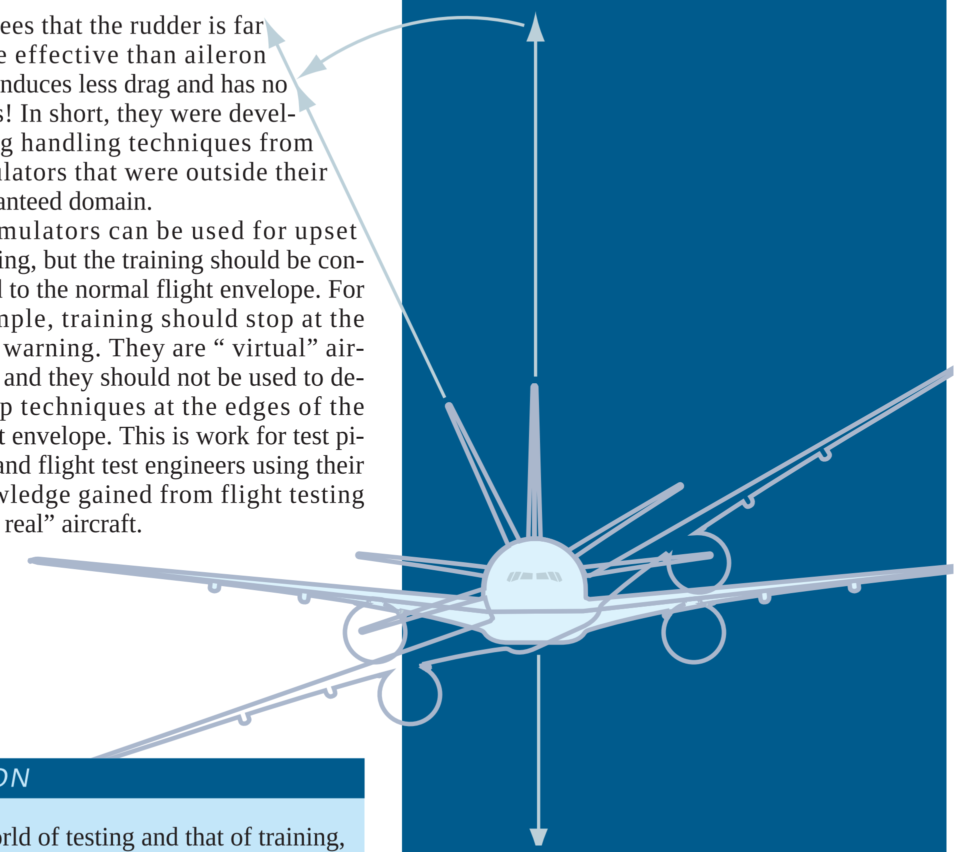
Simulators can be used for upset training, but the training should be confined to the normal flight envelope. For example, training should stop at the stall warning. They are " virtual" aircraft and they should not be used to develop techniques at the edges of the flight envelope. This is work for test pilots and flight test engineers using their knowledge gained from flight testing the " real" aircraft.

Table 1

	Sideslip	Angle of attack
SLATS OUT		
● All Engines Operating	Around neutral Between + 15° and -15°	Between 0°and 22° Between 0° and 12°
● One Engine Inoperative	Between +8° and -8	Between 5° and 12°
SLATS IN, LOW MACH		
● All Engines Operating	Around neutral Between +10° and -10°	Between 0° and 12° Between 2° and 9°
● One Engine Inoperative	Between +8° and -8°	Between 2° and 8°
SLATS IN, HIGH MACH		
● All Engines Operating	Around neutral Between +5° and -5°	Between 0° and 5° Between 1° and 3°
● One Engine inoperative	Between +2° and -2°	Between 1° and 3°

Table 2

	Sideslip	Angle of attack
SLATS OUT	From +18° to -18°	From -5° to 25°
SLATS IN, LOW MACH	From +18° to -18°	From -5° to 12°
SLATS IN, HIGH MACH	From + 8° to -8°	From -2° to 8°



CONCLUSION

It may seem that there is a gulf between the world of testing and that of training, but the message that I would like to get over in this article is that we can all learn from each others' experiences and that we should not do things in isolation. It is all about working together, which is what we all did when we met to prepare and review this training aid, even though we sometimes had some very lively sessions. And there is one word that crops up frequently: compromise. Life is a compromise, and you always have to search for that ideal point between two extremes which Aristotle called "the golden mean". By finding suitable compromise solutions, our two worlds of testing and training were able to resolve their differences and develop something that satisfied everyone.

Of course there are also some points about piloting that were raised during our discussions which I feel should have a larger audience. They are important, but they should be kept in context. On the whole they are related to recovery of an aircraft which is already out of control, or is about to be. This is an area in which the test pilots have some experience which other pilots do not normally have, because the aim of training should be to prevent an aircraft getting into such a situation. The end result of all the discussions that took place was to concentrate everyone's attention on taking action early enough to prevent the occurrence of loss of control. We put the emphasis on training within the known flight envelope, and to avoid going into that part which cannot be guaranteed one hundred per-cent and which may have a negative effect.

In conclusion, we must use each other's competences in the areas where they are expert. Of course the training programmes must be designed by training pilots, but these training programmes must stay in a reasonable flight envelope. And the test pilots are best qualified to define the flight envelope that should be used. That is what we now have with this joint industry training aid, which is a very good example of how we can all work together in everyone's interest. ■

Concentrate everyone's attention on taking action early enough to prevent the occurrence of loss of control.